Sustainable Agricultural Intensification Research and Learning in Africa

Smallholder Risk Management Solutions (SRMS) in Malawi and Ethiopia

Commercialising teff in Ethiopia:
A risk simulation game

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(Revised Version)

Prepared by on behalf of SAIRLA

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Acronyms

Acronym	
ARARI	Amhara Agricultural Research Institute
DAP	Diammonium Phosphate
ETB	Ethiopian birr
FGD	Focus Group Discussions
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
OPM	Oxford Policy Management
RBM	Replicable Business Model
SAIRLA	Sustainable Agricultural Intensification Research and Learning in Africa
SRMS	Smallholder Risk Management Solutions
SPSS	Statistical Package for the Social Sciences

Note: in 2017, 1 US dollar (USD) = 27 Ethiopian birr (ETB)

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Abstract

Smallholder commercialisation is constrained by systemic risks. Business models to reduce these risks focus on correcting market failures but pay less attention to risks from natural shocks. We developed a replicable business model (RBM) to reduce market risks for the commercialisation of teff in South Wollo Zone, Amhara region, Ethiopia. To test the robustness of this RBM to natural shocks, we designed a risk simulation game to capture the impact of variable rainfall on teff production and commercialisation. We captured farmers' decision-making for four rainfall scenarios and three levels of market prices. The game showed that variable rainfall had little impact on the levels of teff production or commercialisation. In a failed Belg season or in a late Meher season, farmers adapted by varying the area planted to teff and the share of teff that received inorganic fertiliser. The exception was the scenario where rainfall failed in both crop seasons. However, the probability of this scenario is low. Resource constraints – particularly shortage of land – limited farmers' production of teff. However, the game revealed that farmers will increase teff sales in response to higher prices. The risk simulation game provides a diagnostic tool to evaluate the performance of the RBM and the wider potential for smallholder commercialisation in the face of natural shocks.

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1 Introduction

Commercialisation is widely viewed as a viable pathway out of poverty for smallholders in Africa. Optimism about commercialisation is fuelled by the rapid growth of urban and global markets. However, the participation of smallholders in these markets is limited by systemic risks (OPM, 2016). These include economic coordination risks, which reduce both the incentives for buyers to source crops from small-scale growers and smallholders' access to inputs like fertiliser and improved seed. Smallholders also face price risks because markets are thin, causing sudden drops in price, and they may lack knowledge of market prices. Opportunism risks may result in the purchase of adulterated or low-quality inputs. Finally, the risk of natural shocks – particularly drought – is high where smallholders lack access to irrigation.

Value chain development to reduce systemic risks has focused primarily on improving market linkages. Typically, this requires the formation of farmer groups, which reduce economic coordination risks through collective marketing and bulk-buying of inputs, reduce price risks by negotiating more favourable prices from buyers and suppliers, and reduce opportunism risks by sourcing higher-quality inputs. By contrast, value chain development has paid less attention to the impact of systemic risks from natural shocks. Yet the risk of natural shocks is high, particularly in rainfed, unfavourable environments, and their impact on smallholder value chains is potentially devastating. Natural shocks not only reduce farmers' ability to produce crops for the market but may also reduce their willingness to participate in certain value chains. Consequently, the systemic risk posed by natural shocks can severely limit the potential benefits of commercialisation to smallholders.

Teff in Ethiopia is a prime example. Demand for teff is increasing thanks to a growing urban population and rising incomes (Orr *et al*., 2017). Research on the teff value chain has revealed scope for improved economic coordination. While there seems to be no need for collective marketing – the value chain for teff is competitive and growers receive the lion's share of the final market price – there is a recognised need to improve the seed system that supplies smallholders with improved teff varieties (Minten *et al*., 2013a; 2013b). However, smallholder agriculture in Ethiopia is also vulnerable to natural shocks, particularly drought. In 2015 – an El Niño year – farmers in our study area of South Wollo reported that yields of cereal crops in the main cropping season were down by 75% (Agriculture Knowledge, Learning, Documentation and Policy (AKLDP), 2016). Thus, the development of the value chain for teff requires not just an improved seed system but also better knowledge of how the risk of variable rainfall might affect smallholder commercialisation.

The SRMS project has developed an RBM to improve smallholders' access to certified seed of improved teff varieties (Weber and Tiba, 2017). The RBM takes the form of a seed revolving fund where smallholders receive 4 kg of seed of an improved teff variety and return 8 kg of grain after harvest. The performance of this RBM depends on several factors (Orr *et al*., 2018b). One important factor is the risk posed by variable rainfall, which will determine how much teff smallholders harvest. In a bad year, smallholders may be unable or unwilling to repay grain after harvest. However, the scale and probability of this risk are not known. In this report, we try to fill this knowledge gap and provide the SRMS project with information on how variable rainfall will affect the performance of its business model.

The general objective of this report is to analyse the potential impact of variable rainfall on the commercialisation of smallholder teff production. The specific objectives are to:

1) Develop a socio-economic profile of the smallholders in the business model;
2) Analyse the effects of variable rainfall on the commercialisation of teff; and
3) Assess the implications for the performance of the business model.

To help answer these questions, we developed a risk simulation game. Farmers were presented with three different rainfall scenarios and asked to choose which cereal crops they would plant and fertilise. Based on these choices, the game simulated cereal production for each rainfall scenario. Farmers were then asked

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how much of the teff produced in each scenario they would keep for home consumption and how much they would sell, for three sets of market prices. The results allow us to quantify the potential impact of variable rainfall on the commercialisation of teff.

The application of simulation games to smallholder agriculture is nothing new. An early example is the *Green Revolution* game, which simulates farmer decision-making for irrigated rice in India (Chapman, 1973; Corbridge, 1985). More recently, the *African Farmer* game simulates farmer decision-making for rainfed agriculture (Farmer Futures, 2016). Both these games operate at the farm level. Other games focus on a single crop. *Faridpur*, a simulation game developed for rainfed lowland rice in Bangladesh, asks players to make crop management decisions on fertiliser, crop protection, and hired labour based on rainfall scenarios that are randomly generated from historical daily rainfall data (Huke, 1985). Unlike conventional decision trees, which are limited in the number of decisions they can handle (Gladwin, 1989), computerised games allow us to model a wide range of decisions, to explore the interaction between them, and to assess their cumulative effects.

The simulation game presented here differs from these examples in three ways. First, it focuses solely on the risk from natural shocks, in this case variable rainfall, and does not include other aspects of decision-making that influence commercialisation. Second, it was designed not as a learning tool for students or researchers but as a game that could be played by real farmers to give insights into actual decision-making. Third, the game is light on data. It does not require meteorological data or rely on expert knowledge of crop modelling. Rather, it relies on stylised rainfall scenarios and information that can be obtained directly from farmers. Although the game was designed for teff in Ethiopia, the basic design can be adapted to fit a variety of contexts and smallholder value chains. Our aim has been to develop a diagnostic tool for practitioners that can provide useful information for action research on smallholder value chains.

The report is organised as follows. The next section describes data and methods. Section 3 provides a socio-economic profile of the sample farmers, while Section 4 analyses farmers' perceptions of systemic risks. In Section 5 we present the results of the risk simulation game. The final section concludes with the implications of these results for the future performance of the RBM.

2 Data and methods

The SRMS project operates in Tehuledere woreda. This woreda was selected in the inception phase by three project partners – the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Amhara Agricultural Research Institute (ARARI), and Wollo University (Orr *et al.*, 2017). Three kebeles in this woreda (Hitecha, Gobeya, and Basso Mille/Jare) were then selected by participants in the value chain workshop (Weber and Tiba, 2017). The kebeles were purposely selected because they were already the site of complementary research activities by ICRISAT and Wollo University and they were accessible from Dessie Town.

2.1 Household survey

The development agent in each of the three farmer cooperatives identified 100 cooperative members to receive 4 kg of certified seed of improved teff varieties. Recipients were selected based their reputation as 'good' farmers and the expectation that they could be trusted to return 8 kg of teff grain to the cooperative after harvest. The cooperatives kept a written record of farmers selected to receive seed and this list was as the sampling frame for the survey. Since the total number of farmers selected to receive certified seed in Year 1 was quite small – 300 farmers – we decided to interview all the farmers listed rather than just a sub-sample. Of the 300 selected farmers, 21 could not be interviewed because of irregularities in the distribution of improved seed. As a result, only 279 farmers (93%) on the list of 300 were successfully reached and interviewed. Of these, 18 proved to be members of the same family. To avoid distorting the results, only the cases where the respondent was the head of the household were included in the analysis. Consequently, the final sample size was 261 households.

2.2 Risk aversion score

To measure farmers' degree of risk aversion, we adapted the approach used by Holden and Westberg (2016). This asks farmers to choose between two crops, the first with a high yield in a good year and a low yield in a bad year, the second with lower yields in both good and bad years. By progressively reducing yields over six choices, farmers can be categorised into six ranks based on their degree of risk aversion. The higher the rank, the greater the degree of risk aversion. We have called this a "risk aversion score". Pre-testing this approach revealed that farmers were confused by the labels 'good' and 'bad' years, relating the suggested crop yields to experience on their own fields. This confusion was overcome when we re-labelled 'good' and 'bad' years as 'Crop 1' and 'Crop 2' and explained that this was an imaginary experiment and not based on their own experience.

2.3 Data collection and processing

The questionnaire was designed by the lead author, who pre-tested the questionnaire in the three kebeles in May 2018. The survey was administered in early April 2018 under the supervision of Oxford Policy Management (OPM). The enumerators were staff members from Wollo University with previous experience of household surveys. Data were collected on hand-held tablets. The dataset was cleaned, stored and analysed using the Statistical Package for the Social Sciences (SPSS).

2.4 Focus group discussions (FGDs)

The information required for the game was obtained through two FGDs held with farmers in Gobeya and Basso Mille/Jare kebeles. The farmers who participated were cooperative members who had received improved teff seed. The FGD was designed to model three rainfall scenarios. First, farmers described a 'good' crop year. They described the months of planting and harvesting for three cereal crops (sorghum, teff, and wheat). Second, farmers provided the same information for a crop year when the Belg season was 'bad' but the Meher season was 'good'. Third, farmers provided the same information for a crop year when the Belg season was 'bad' and the Meher season was 'late', with rain arriving in August rather than July. Information was not collected about the fourth scenario (failed Belg and Meher seasons), which results in almost complete crop failure. For the purpose of the simulation game, we assumed that teff production and sales in this scenario were zero. Farmers also provided information on the average yield (with and without fertiliser) for each crop in each of the three rainfall scenarios.

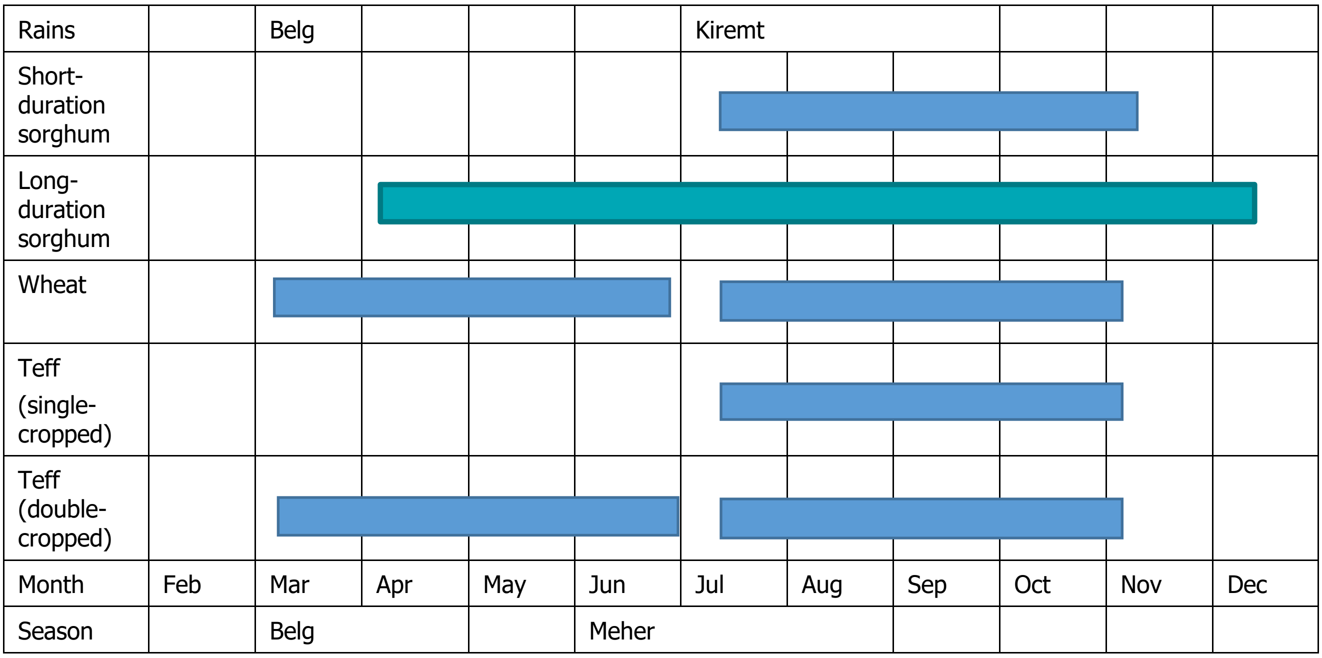
3 Designing the risk simulation game

3.1 The context

Amhara region lies in the north-western Highlands of Ethiopia. In terms of area planted, teff is the most important crop, with 1 million ha, followed by sorghum (600,000 ha), wheat (500,000 ha), and maize (400,000 ha). Over 2.5 million smallholders in Amhara plant teff and the region accounts for 38% of national teff production (Orr *et al.*, 2016). The optimal growing conditions for teff are between 1,800 and 2,100 metres asl (Chamberlin and Schmidt, 2012). Our research site – Tehuledere woreda in South Wollo Zone – lies in the *woina dega* agro-ecological zone, which is comprised of midlands approximately 1,500–2,000 metres asl.

Cereal crops in Ethiopia have two growing seasons. Any crop harvested between March and August is a Belg season crop, while crops harvested between September and February are Meher season crop. Meher is the main cropping season and accounts for 75% of cereal production in Amhara. Figure 1 shows the crop calendar for Tehuledere.

Figure 1: Cereal crop calendar in Tehuledere woreda, South Wollo Zone



Source: FGDs, Gobaya and Basso Mille/Jare kebeles, Tehuledere woreda, South Wollo, Amhara region.

3.2 Rainfall scenarios

Cereal crops in Ethiopia face systemic risks from natural shocks. We asked our sample farmers to rank the relative importance of these shocks for crop yields. Farmers ranked natural shocks from drought significantly higher than shocks from insect pests or plant diseases. Based on the secondary literature, we can identify four types of rainfall risk:

1) *Major drought:* in extreme cases, the rains fail altogether and grain yields are too low to be worth harvesting. The most recent occurrence was in 2015, when El Niño caused the failure of the Belg rains and the late arrival of the Meher rains. In Amhara, crops planted at the start of the Meher

season either failed to germinate or withered in the early growth stages. Farmers replanted in August and even September, but these crops also failed and losses of at least 75% were reported for the season (AKLDP, 2016).

2) *Late onset*: in this case, planting is delayed and crop yields reduced. This is common in the Meher season. An analysis is available for Amhara region using meteorological data for the period 1978–2008 (Ayalew *et al.*, 2012). We have used the dates of onset for the Kombolcha meteorological station, which is the closest to the town of Dessie. In half the years, the median date for the onset of rain was 4 July, but in one quarter of the years the median date was 18 July (Ayalew *et al.*, 2012). In other words, there is a one-in-four chance that planting in the Meher season will be two weeks late.
3) *Erratic distribution*: crop yields reflect rainfall in specific months. Teff production is highly correlated with rainfall in August and September, while the production of sorghum is strongly correlated with rainfall in May and June (Bewket, 2007). Conversely, inadequate rainfall in any of these months will reduce yields for cereal crops.
4) *Shorter rains:* rainfall data for the 30-year period 1980–2010 reveal that the Rift Valley, including Amhara region, saw a significant reduction in the quantity of rainfall received in the Belg season (Gummadi *et al.*, 2017). Over time, the consecutive number of dry days increased while the consecutive number of wet days decreased (Gummadi *et al.*, 2017). For our study area of South Wollo, rainfall data for the period 1987–2007 also showed a decline in Belg rainfall and a later start to the Belg season (Rosell, 2011). As a result, a crop model for teff in South Wollo showed that only 18 years (45%) in the period 1964–1996 were suitable for teff in the Belg season (Rosell and Holmer, 2015). Shorter rains in the Belg season increase the risks to cereal crops in both crop seasons, since they also the reduce soil moisture available for crops planted in the Meher season.

Based on this literature, we identified four rainfall scenarios for the risk simulation game:

1) A ‘normal’ season where farmers can plant in March/April in the Belg season and in June/July in the Meher season, and where there is rain in the first two weeks of September when crops are flowering.
2) A failed Belg season where farmers cannot plant in March/April but the Meher season is normal, and farmers can plant in June and July and there is rain in the first two weeks of September when crops are flowering.
3) A failed Belg season where farmers cannot plant in March/April and where the Meher season is late, where farmers cannot plant in June/July but can plant in August, and there is rain in the last two weeks of September when crops are flowering.
4) A failed Belg season where farmers cannot plant in March/April and a failed Meher season where planting is late (August) but there is not enough rain in the last two weeks of September when crops are flowering.

The fourth scenario (failed Belg and failed Meher seasons) results in total crop failure and does not need to be simulated. Thus, only scenarios 1, 2, and 3 were included in the game.

Table 1: Stylised rainfall scenarios for risk simulation game

Rainfall scenario	Description	Rainfall in key months			
		March/April	June/July	August	September
1	Normal Belg and Meher	Normal	Normal	Normal	Normal
2	Failed Belg, normal Meher	Failed	Normal	Normal	Normal
3	Failed Belg, late Meher	Failed	Failed	Normal	Normal
4	Failed Belg and Meher	Failed	Failed	Normal	Failed

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3.3 Yields

Farmers fertilise cereal crops but cannot fertilise all their land because fertiliser is expensive. Hence, fertiliser is rationed. Farmers usually apply fertiliser in two splits, as basal (DAP) and top-dressing (urea). For the purpose of the game, we ignored the timing of fertilisers, and just asked farmers whether they will fertilise the crop or not.

Table 2: Yields used in risk simulation game (quintals/temad)

Crop	Fertilisation	Rainfall scenarios			
		1	2	3	4
Teff (Belg)	Fertilised	3	0	0	0
	Unfertilised	2	0	0	0
Teff (Meher, after teff in Belg)	Fertilised	3	3	3	0
	Unfertilised	1	1	1	0
Teff (Meher, after fallow in Belg)	Fertilised	4	4	4	0
	Unfertilised	3	3	3	0
Wheat (Belg)	Fertilised	2	0	0	0
	Unfertilised	1	0	0	0
Wheat (Meher)	Fertilised	5	5	0	0
	Unfertilised	2	2	0	0
Long-duration sorghum (Belg)	Fertilised	7	0	0	0
	Unfertilised	3	0	0	0
Short-duration sorghum (Meher)	Fertilised	2.5	2.5	2.5	0
	Unfertilised	<1	<1	<1	0

Source: FGDs, Gobaya and Basso Mille/Jare kebeles, Tehuledere woreda, South Wollo, Amhara region.

3.4 Prices

To discover if farmers will increase the volume and share of teff production they sell in response to higher prices, we used three sets of prices, with prices in 2017 as a benchmark and price increases by 15% and 30%.

Table 3: Price levels used in risk simulation game

	Now	Plus 15%	Plus 30%
ETB/quintal	2,400	2,760	3,120
ETB/tassa	30	34	39

Source: FGDs, Gobaya and Basso Mille/Jare kebeles, Tehuledere woreda, South Wollo, Amhara region.

Note: 1 tassa = 4 cups = 1.25 kg.

Teff prices are seasonal, with a difference of 40% between the producer price at harvest and at the end of the season in August–October (Minten *et al.*, 2013a).

3.5 Rules for risk simulation game

To simplify the design of the game, we imposed the following rules:

1. Players cultivate a maximum of five temad of land (0.625 ha);
2. Soil is uniform quality – suitable for any cereal crop;
3. We ignore the cultivation of non-cereal crops;
4. Players can plant any combination of four cereal crops (teff, wheat, long-duration sorghum, and short-duration sorghum);
5. Players can only plant units of one temad (no ½ temads);
6. Players can plant a maximum of three temads of teff in any one season;
7. Fertiliser is rationed to a maximum of three temads in any one season; and
8. Cereal cropping is entirely rainfed and there is no irrigation.

4 The players and their cereal crops

This section introduces the players and provides information on the crop choices and crop management decisions that were modelled in the risk simulation game. The information on crops and crop management relates to 2017, the previous crop year. Farmers are not a homogeneous group. To capture socio-economic differences, we stratified farmers by farm size, which was defined as 'the area suitable for cultivation' (Table 4). This stratification shows some significant differences between the players:

1) Heads of household on the biggest farms were significantly older, but otherwise there were no significant differences in household size, household structure, or the dependency ratio between the farm size terciles.
2) Livestock assets increased with farm size, and bigger farms had significantly more plough oxen, goats, and local cows. As a result, total livestock units and the combined value of livestock were also greater on these farms. By contrast, a significantly higher share of the smallest farms borrowed or rented oxen for ploughing.
3) Household food security was significantly higher on the biggest farms, averaging 10 months for teff and six months for sorghum, compared to the average of seven months and three months on the smallest farms.
4) Many conventional wealth indicators showed no significant differences between farms. These included the share of income from different sources, borrowing to buy food, working as a farm labourer, and the number of households that received government rations of wheat and oil after the El Niño drought of 2016.

Table 4: Socio-economic profile of sample households, by farm size

Variable	Farm size terciles				P-value (*p* > .000
	1 (n=87)	2 (n=87)	3 (n=87)	All (n=261)	
Mean area cultivated (temads) [1]	1.69	3.14	5.23	3.35	.000
Male-headed households (no.)	77	72	78	227	.351
Female-headed households (no.)	10	15	9	34	.351
De jure (no.)	9	8	7	24	.871
De facto (no.)	1	7	2	10	.040
Age of household head (years)	43	49	50	48	.001
Education of household head (primary and above) (no.)	52	58	54	164	.768
Children < 15 (no.)	1.2	1.2	1.1	1.2	.424
Adults 60 > (no.)	0.3	0.4	0.4	0.4	.535
Females 15-60 (no.)	1.8	2.3	2.1	2.1	.517
Males 15-60 (no.)	2.1	1.6	2.1	1.9	.112
Total household size (no.)	5.4	5.4	5.7	5.5	.874
Dependency ratio	0.55	0.59	0.52	0.55	.742
Households without plough oxen (no.)	22	16	16	54	.066
Plough oxen (no.)	1.1	1.3	1.3	1.2	.039
Households renting/borrowing oxen (no.)	69	52	56	187	.091

Improved cows (no.)	0.2	0.3	0.3	0.3	.318
Local cows (no.)	0.4	0.5	0.6	0.5	.042
Donkeys (no.)	0.5	0.4	0.7	0.6	.517
Goats (no.)	0.7	1.5	1.3	1.1	.077
Sheep (no.)	0.3	0.4	0.3	0.3	.837
Total value of livestock (ETB)	35,241	46,435	47,471	43,019	.010
Total livestock units	3.2	4.6	4.4	4.1	.003
Households owning sprayer (no.)	31	35	29	95	.629
Value of main dwelling house	7.2	7.3	7.8	7.4	.124
Income from agriculture (%)	69	72	77	73	.380
Income from trade/business (%)	3	4	1	3	.225
Income from other sources (%)	28	24	22	24	.587
Households working as farm labour (no.)	11	8	6	25	.431
Households hiring farm labour (no.)	11	10	27	48	.001
Households using exchange labour (no.)	80	81	84	245	.421
Households borrowing to buy food (no.)	27	19	22	68	.377
Households receiving food rations from government in 2016 (no.)	24	18	16	58	.316
Household eats own teff (months)	7.3	8.1	9.9	8.4	.000
Household eats own sorghum (months)	3.3	4.6	6.1	4.7	.001
Household eats own wheat (months)	2.9	2.5	3.5	3.0	.194

Source: SRMS Household Survey, 2018.

[1] One temad = 0.125 ha.

Farmers in the study area planted cereal crops in both the Belg and Meher seasons. However, cereals were not widely grown in the Belg season. Table 5 shows that:

1) The area planted to cereal crops was small, averaging just 1 temad;
2) Teff was the most popular cereal crop, followed by late-maturing sorghum;
3) One-third of farmers applied inorganic fertiliser;
4) Improved teff varieties had the highest fertiliser rate;
5) Yields were highest for late-maturing sorghum; and
6) Crop management practices did not differ significantly by farm size.

By contrast, in the main Meher season the area planted to cereal crops was greater and farmers applied higher rates of inorganic fertiliser. Table 6 shows that:

1) The area planted to cereal crops was three times higher, averaging 3 temads;
2) Teff was the most popular cereal crop, followed by early-maturing sorghum;
3) Eight-five percent of farmers applied inorganic fertiliser;
4) Improved teff varieties again had the highest fertiliser rate; and
5) Yields were highest for early-maturing sorghum.

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Table 5: Cereal crops and crop management in the Belg season, 2017, by farm size

Variable	Farm size terciles				P-value (*p* > .000
	1 (n=87)	2 (n=87)	3 (n=87)	All (n=261)	
Area planted to improved teff (temads)	.287	.322	.368	.326	.769
Area planted to local teff (temads)	.080	.115	.241	.146	.039
Area planted to late-maturing sorghum (temads)	.195	.218	.264	.235	.859
Area planted to wheat (temads)	.172	.138	.161	.157	.862
Area planted to maize (temads)	.103	.276	.276	.218	.011
Total area planted to cereal crops (temads)	.084	1.07	1.31	1.07	.007
Area planted to improved teff that received pesticide (temads)	.103	.138	.126	.123	.894
Area planted to local teff that received pesticide (temads)	.057	.034	.092	.061	.471
Urea applied to improved teff (kg/temad)	4.06	3.88	3.70	3.89	.993
Urea applied to local teff (kg/temad)	1.00	1.38	2.88	2.10	.744
DAP applied to improved teff (kg/temad)	12.44	10.94	16.74	13.75	.757
DAP applied to local teff (kg/temad)	5.67	9.00	5.00	6.20	.745
Yield of improved teff (quintals/temad)	0.77	0.88	1.82	1.22	.027
Yield of local teff (quintals/temad)	1.63	1.85	2.06	1.80	.215
Yield of late-maturing sorghum (quintals/temad)	2.56	6.14	2.30	3.42	.025
Yield of wheat (quintals/temad)	5.2	1.3	2.4	3.1	.486
Bought fertiliser from coop (no.)	20	19	19	58	.978
Bought fertiliser from local market (no.)	5	6	9	20	.495
Reasons for not buying fertiliser (no.)					
No need because the soil is good	10	8	14	32	.330
Don't know best way to apply	2	2	0	4	.363
Fertiliser was not available	1	1	0	2	.604
No money to buy fertiliser	4	7	3	4	.363
The quality of fertiliser is not good	0	1	0	1	.372
No transport available	2	0	2	4	.354
Other	32	33	28	93	.676

Source: SRMS Household Survey, 2018.

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Table 6: Cereal crops and crop management in the Meher season, 2017, by farm size

Variable	Farm size terciles				P-value (*p* > .000
	1 (n=87)	2 (n=87)	3 (n=87)	All (n=261)	
Area planted to improved teff (temads)	1.61	2.15	2.46	2.07	.000
Area planted to local teff (temads)	0.40	0.45	0.67	0.51	.120
Area planted to early-maturing sorghum (temads)	0.29	0.33	0.71	0.44	.594
Area planted to wheat (temads)	0.24	0.31	0.31	0.29	.582
Total area planted to cereal crops (temads)	2.54	3.24	4.16	3.31	.000
Area planted to improved teff that received pesticide (temads)	1.32	1.74	1.97	1.67	.009
Area planted to local teff that received pesticide (temads)	0.00	0.00	0.00	0.00	Na.
Urea applied to improved teff (kg/temad)	9.33	13.79	18.43	13.89	.005
Urea applied to local teff (kg/temad)	4.61	5.08	3.52	4.37	.835
DAP applied to improved teff (kg/temad)	23.80	25.85	29.59	26.43	.303
DAP applied to local teff (kg/temad)	9.65	15.79	9.81	11.70	.426
Yield of improved teff (quintals/temad)	2.37	2.84	3.67	2.96	.000
Yield of local teff (quintals/temad)	1.61	1.88	2.85	2.15	.113
Yield of early-maturing sorghum (quintals/temad)	2.73	2.69	5.00	3.69	.010
Yield of wheat (quintals/temad)	1.35	1.92	2.17	1.84	.034
Bought fertiliser from coop (no.)	64	62	65	191	.872
Bought fertiliser from local market (no.)	10	10	10	30	1.000
Reasons for not buying fertiliser (no.)					
No need the soil is good	4	2	7	13	.058
Don't know best way to apply	1	0	0	1	.338
Fertiliser was not available	1	0	0	1	.338
No money to buy fertiliser	5	4	3	12	.711
Other	3	6	6	15	.427

Source: SRMS Household Survey, 2018.

5 Results of the risk simulation game

The risk simulation game was designed as a separate module in the household survey, in which we interviewed 267 households that had received certified seed. Hence, the players were those interviewed for the survey, namely the head of the household. The hand-held tablet devices were specifically programmed for the game so that the various scenarios would be generated by the computer in an interactive way. In this section, we summarise the results of the game. We compare the area planted to different cereal crops, the share of area fertilised, production, and the quantity offered for sale at three levels of prices for each of the three scenarios. In addition, we present results for an 'average' rainfall scenario. This 'average' was derived by asking the players to estimate the frequency of the four rainfall scenarios in Table 1 over the past 10 years. The results were 2.8 years (good Belg and Meher), 3.8 years (failed Belg, good Meher), 2.0 years (failed Belg, late Meher) and 0.18 years (failed Belg and Meher). In combination, therefore, these four scenarios accounted for 8.72 years of the previous 10 years, with the residual 1.28 years representing rainfall scenarios that are not captured by our 'average' scenario.

Table 7 compares results for these four scenarios, using Scenario 1 as the baseline for comparison.

Scenario 1: Good Belg and Meher seasons

In the Belg season, players allocated more land to wheat (2.59 temads) than to teff (1.45 temads). They planted only a small area of long-duration sorghum (0.64 temads). In the Meher season, players allocated more land to teff (2.53 temads) than to wheat (1.20 temads) or early-maturing sorghum (0.32 temads). Teff also received priority for fertiliser (79% fertilised). Over the two crop seasons, teff production totalled 13.69 quintals, evenly split between the Belg (6.98 quintals) and Meher seasons (6.71 quintals). Given this level of teff production, players would sell 2.17 quintals of teff at current prices, increasing to 2.71 quintals if market prices rose by 30%.

Scenario 2: Failed Belg season, good Meher season

In this scenario players compensated for a failed Belg season by increasing the area planted to teff (2.78 temads), wheat (1.46 temads), and early-maturing sorghum (0.62 temads). Once again, teff received the highest priority for fertiliser (74%). Total production of teff was 10.79 quintals or 2.9 quintals lower than in Scenario 1, when rains were good in both seasons. Given this level of teff production, players reduced the amount of teff offered for sale to 1.3 quintals at current prices, increasing to 1.78 quintals if market prices rose by 30%.

Scenario 3: Failed Belg season, late Meher season

In this scenario players increased the area planted to teff (2.89 temads) and short-duration sorghum (1.27 temads) at the expense of wheat (0 temads). Once again, teff was given highest priority for fertiliser and the share of teff fertilised increased to 86%. As a result, despite the late rainfall, players were able to maintain their level of teff production (11.24 quintals). Given this level of teff production, the quantity of teff offered for sale at current prices was 1.39 quintals, rising to 1.90 quintals if market prices rose by 30%.

'Average' scenario

In this scenario the production of teff was 11.44 quintals, split between the Belg (2.21 quintals) and Meher seasons (9.19 quintals). Teff received the highest priority for fertiliser in both seasons. Seventy-eight percent of the area planted to teff was fertilised in the Meher season, compared to 38% for wheat and just 17% for short-duration sorghum. At this level of teff production, players offered 1.57 quintals of teff for sale at current prices, rising to 2.07 quintals when market prices rose by 30%.

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Table 7: Results of the risk simulation game

Variable	Rainfall scenario				
	Good Belg and Meher seasons	Failed Belg, good Meher	Failed Belg, late Meher	Failed Belg and Meher	Weighted scenarios
	Belg season				
Area planted to teff (temads)	1.45				0.82
Area planted to wheat (temads)	2.59				0.46
Area planted to long-duration sorghum (temads)	0.64				0.20
Area unplanted (fallow) (temads)	0.32				0.10
Area planted to teff that received fertiliser (%)	69.2				69.1
Area planted to wheat that received fertiliser (%)	44.8				44.8
Area planted to long-duration sorghum that received fertiliser (%)	19.5				19.5
Teff production (quintals)	6.98				2.21
Wheat production (quintals)	2.07				0.66
Total cereal production (quintals)	9.36				2.97
	Meher season				
Area planted to teff (temads)	2.53	2.78	2.89		2.67
Area planted to wheat (temads)	1.20	1.46	0.00		1.01
Area planted to short-duration sorghum (temads)	0.32	0.62	1.27		0.66
Area unplanted (fallow) (temads)	0.31	0.15	0.84		0.36
Area planted to teff that received fertiliser (%)	79.2	73.5	85.7		78.3
Area planted to wheat that received fertiliser (%)	43.8	33.9	0.00		37.9
Area planted to short-duration sorghum that received fertiliser (%)	31.0	33.7	15.0		16.8
Teff production (quintals)	6.71	10.39	11.15		9.19
Wheat production (quintals)	3.9	4.26	0.00		3.06
Short-duration sorghum production (quintals)	0.34	0.58	1.03		0.46
Long-duration sorghum production (quintals)	1.46	0.00	0.00		0.60
Total cereal production (quintals)	12.35	15.22	12.19		13.30
Total Belg and Meher seasons	**Combined Belg and Meher seasons**				
Total teff production (quintals)	13.69	10.42	11.24		11.44
Total long-term sorghum production (quintals)	1.46	0.00	0.00		0.46
Total short-duration sorghum production (quintals)	0.34	0.58	1.03		0.60

Total quantity of wheat produced (quintals)	5.9	4.3	0.00		3.71
Total cereal production (quintals)	21.40	15.26	12.29		16.21
	Price scenarios				
Teff sold at price now (quintals)	2.17	1.30	1.39		1.57
Teff sold at price now + 15% (quintals)	2.00	1.23	1.30		1.46
Teff sold at price now + 30% (quintals)	2.71	1.78	1.90		2.07
Increase in sales with 30% increase in price (%)	+ 24.9	+ 36.9	+ 43.2		+31.8

Source: Risk simulation game.

The results of the risk simulation game give useful insights into farmers' decision-making for the production and sale of teff in the project area:

1) Farmers attached a high priority to maintaining a consistent level of teff production in the face of variable rainfall. They achieved this by increasing the area planted to teff in poor seasons and upping the share of teff that received fertiliser at the expense of other crops. Even when rains failed in the Belg season or when rainfall in the Meher season was late, the volume of teff production showed remarkably little fluctuation. Even in a scenario where rains failed in both crop seasons – as in the El Niño year in 2016 – teff production at the national level proved remarkably resilient (Bachewe *et al.*, 2017).
2) Teff production depends on rainfall in the Meher season. Taking an average over the four rainfall scenarios, the Meher season contributed about four-fifths of the total volume of teff production compared to just one-fifth in the Belg season. Climate change has reduced the potential for cereal cropping in the Belg season. However, our results suggest that this will have limited effects on the aggregate level of teff production. Farmers compensate for a failed Belg season by increasing teff production in the Meher season.
3) Farmers prioritised teff over wheat and especially over sorghum. Except for wheat in the Belg season, the area planted to teff is always higher than for wheat and sorghum, and teff also receives the lion's share of inorganic fertiliser. This reflects the value farmers attach to teff as a staple food crop rather than its value as a source of cash income. Obviously, the "opportunity cost" of this decision is to reduce the production of wheat and sorghum. However, this reduction is compensated by a higher production of teff. In terms of cereal production, the decision to prioritize teff in Scenarios 2 and 3 results in a slight increase in the aggregate production of cereals. Hence the decision to prioritize teff safeguards household food security.
4) Teff is used primarily for home consumption rather than for sale. At current prices, the volume of teff offered for sale ranged from 1.3 to 2.17 quintals per household. If prices rose by 30%, the volume offered for sale ranged from 1.78 to 2.71 quintals per household. For an 'average' season, this represented an increase of 32%. While the average volume of teff sales is low, then, farmers will increase the amount of teff they sell in response to higher prices.
5) A surprising result was the relatively low small area that farmers chose to plant to long-duration sorghum in a good Belg season and to short-duration sorghum in a good Meher season. This suggests that farmers view sorghum primarily as a strategy for managing the risk of variable rainfall. Long-duration sorghum (Ahyo or Gedalit) is planted in order to have some yield late in the Meher season, while short-duration sorghum (Gerana 1) is planted when rain in the Meher season arrives too late to plant wheat.

In a separate exercise, farmers were asked to rank cereal crops in terms of the risk of yield loss from variable rainfall. Farmers considered long-duration sorghum to be the most risky crop, followed by wheat. However, there was no significant difference between short-duration sorghum and teff. These results help explain why long-duration sorghum was not widely planted, but they do not explain why short-duration sorghum was less popular than wheat.

6 Prospects for commercialisation

In this section, we review the prospects for the commercialisation of teff. The results presented here derive not from the simulation game but from the household survey, and refer to the previous crop year (2017). Generally, the level of commercialisation was low. Only one-quarter (26%) of these households had sold any teff in the previous year, and the average quantity sold was 0.4 quintals, valued at ETB 617 (Table 8). This represented just 12% of the total value of crops sold and 8% of the total value of livestock sales. Clearly, cereal crops were grown primarily for home consumption and contributed little to households' cash income.

Future prospects for increasing the level of teff commercialisation are limited by resource constraints. About half the sample households (51%) reported that they could not increase the area planted to teff because of a shortage of land. Thus, a strategy to promote the commercialisation of teff will require intensification to raise teff yields through the adoption of improved varieties and the application of higher rates of inorganic fertiliser. This finding supports the SRMS project strategy of increasing farmers' access to improved seed. A further 14% of farmers reported that they could not increase the area planted to teff because of a shortage of labour. The most labour-intensive operations are weeding and threshing. Thus, further commercialisation will also require the introduction of labour-saving innovations for these crop management operations.

Commercialisation is also limited by the priority farmers give to household food security. Farmers reported that they required an average of 4.4 quintals of teff to feed their families. Above this, additional teff is required for seed and sharing with relatives. Consequently, farmers needed to produce 10 quintals of teff before they were willing to sell. However, our enumerators got the impression that farmers would not necessarily keep all the teff they required for consumption but would sell teff and buy other food with the money earned. Selling high-priced teff to buy cheaper sorghum was a common practice.

Contrary to our expectations, there was no significant difference between bigger and smaller farmers in their risk aversion score. The average score was three, and thus near the middle of the six possible ranks, which suggests that farmers were not severely but moderately risk averse. The absence of a significant difference implies that aversion to risk is not a constraint on commercialisation among smaller farmers.

Table 8: Teff commercialisation, by farm size

Variable	Farm size terciles				P-value (*p* > .000
	1 (n=87)	2 (n=87)	3 (n=87)	All (n=261)	
Risk aversion score	2.76	2.61	3.15	2.84	.182
Growers selling teff (%)	17	22	29	68	.112
Growing selling sorghum (%)	5	13	14	32	.229
Growers selling wheat (%)	3	4	2	9	.682
Total teff production (quintals)	2.99	3.62	5.35	3.99	.000
Total teff sold (quintals)	0.20	0.34	0.67	0.40	.393
Total sorghum sold (quintals)	0.01	0.01	0.10	0.04	.326
Value of teff sold (ETB)	254	542	1055	617	.005
Value of sorghum sold (ETB)	27	141	216	128	.039
Value of cereals sold (ETB)	284	714	1301	766	.002
Total value of crops sold (ETB)	3,430	4,847	7,262	5,180	.000
Total value of livestock sold (ETB)	8,810	4,712	10,770	8,247	.004

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Can increase land planted to teff? (No)	42	45	40	132	.550
Shortage of land (no.)	42	41	34	117	.663
Land not suitable for teff (no.)	2	9	5	16	.069
Shortage of labour (no.)	3	12	11	36	.017
Other (no.)	7	8	10	25	.473
Teff needed to feed family (quintals)	4.6	8.8	5.6	4.4	.290
Teff needed for sale (quintals)	7.3	14.3	10.0	9.8	.273

Source: SRMS Household Survey, 2018.

7 Conclusions

The general objective of this report was to analyse the potential impact of variable rainfall on the commercialisation of smallholder teff production. We developed a risk simulation game in which farmers made decisions about the area planted to cereal crops, fertiliser use, and teff sales for three different rainfall scenarios.

A socio-economic profile of the farmer-players showed significant heterogeneity in the amount of land suitable for cultivation, ownership of livestock, and household food security. However, there was no significant relationship between farm size and aversion to risk, which implies that risk aversion is not a significant barrier to commercialisation on smaller farms.

Variable rainfall did not have the expected negative impact on the production and commercialisation of teff. We simulated farmer decision-making for failed rainfall in the Belg season and late rains in the Meher season. In both cases, farmers were able to adapt to variable rainfall and maintain their level of teff production by increasing the area they planted to teff and the share of teff that received fertiliser. Although the area planted to wheat and sorghum declined, there was no reduction in the aggregate production of cereals. When the rains failed in both seasons, these risk management strategies were redundant and there was no production of teff. However, the risk of consecutive failed seasons is low. Farmers estimated that this scenario occurred only 0.2 times in the last 10 years. We therefore conclude that variable rainfall will have a limited impact on the performance of the RBM.

Commercialisation of teff is at a low level because of resource constraints. Limited land and labour mean that farmers use teff primarily as a staple food crop and leave only a small amount for sale. Teff sales in the past year averaged 0.4 quintals and accounted for just 12% of the total value of crop sales. However, the risk simulation game suggests that farmers will increase sales in response to higher prices. In the average rainfall scenario, a 30% increase in prices resulted in an increase of 32% in teff sales. Raising the level of commercialisation thus requires a strategy that combines increasing supply through higher yields with increasing demand through higher prices.

The risk simulation game provides a diagnostic tool to test the potential impact of variable rainfall on the commercialisation of teff in Ethiopia. Similar tools are needed for other contexts where a high risk of natural shocks may disrupt sales and reduce market participation. Games can be easy to design and administer to farmers. As this example shows, they can give useful insights into farmer decision-making and their capacity for adaptation to risks from natural shocks.

References

AKLDP (2015) *El Niño in Ethiopia: Uncertainties, impacts and decision-making. Technical Brief*. September. Mimeo, 6 pp. http://www.agri-learning-ethiopia.org/wp-content/uploads/2015/09/AKLDP-El-Nino-brief-Sept-2015.pdf

AKLDP (2016) *El Niño in Ethiopia: Early impacts of drought in Amhara National Regional State. Field Notes.* January. Mimeo, 6 pp. https://reliefweb.int/sites/reliefweb.int/files/resources/akldp-field-notes-amhara-jan-2016.pdf

Ayalew, D., Tesfaye, K., Mamo, G., Yitaferu, B., and Bayu, W. (2012) 'Variability of rainfall and its current trend in Amhara region, Ethiopia'. *African Journal of Agricultural Research* 7(10): 1475–1486.

Bachewe, F., Yimer, F., and Minten, B. (2017) 'Agricultural price evolution in drought versus non-drought affected areas in Ethiopia: An updated assessment using national producer data (January 2014 to January 2017)'. *Working Paper No. 106. Ethiopia Strategy Support Program*. Addis Ababa: International Food Policy Research Institute.

Bewket, W. (2009) 'Rainfall variability and crop production in Ethiopia: Case study in the Amhara region', pp. 823–836 in S. Ege, H. Aspen, B. Teferra and B. Shiferaw (eds.), *Proceedings of the 16th International Conference of Ethiopian Studies,* Trondheim.

Chamberlin, J. and Schmidt, E. (2012) 'Ethiopian Agriculture: A Dynamic Geographic Perspective', pp. 21–52 in P.A. Dorosh and S. Rashid (eds.), *Food and Agriculture in Ethiopia: Progress and Policy Challenges*. Philadelphia: University of Pennsylvania Press.

Chapman, G. P. (1973) 'The Green Revolution: A Gaming Simulation', *Area*, 5 (2): 129–140.

Corbridge, S. (1985) 'The green revolution game'. *Journal of Geography in Higher Education*, 9 (2): 171–175.

Futures Agriculture Consortium (2018) *African Farmer*. www.africanfarmergame.org/

Gladwin, C. H. (1989) *Ethnographic Decision Tree Modeling.* Qualitative Research Methods Series No. 19. Beverly Hills, CA: Sage Publications.

Gummadi, S., Rao, K. P. C., Seid, J., Legesse, G., Kadiyala, M. D. M., Takele, R., Amede, T., and Whitbread, A. (2017) 'Spatio-temporal variability and trends of precipitation and extreme rainfall events in Ethiopia in 1980–2010'. *Theoretical and Applied Climatology*, December (published online).

Holden, S. T. and Westberg, N. B. (2016) 'Exploring technology use under climate risk and shocks through an experimental lens'. *African Journal of Agricultural and Resource Economics*, 11(1): 47–62.

Huke, R. E. (1985). *Faridpur: A Computer-Assisted Instruction Model for Rainfed Lowland Rice*, IRRI Research Paper Series, No. 104. December. Los Banos, Philippines: International Rice Research Institute.

Minten, B., Tamru, S., Engida, E. and Kuma, T. (2013a) 'Using Evidence in Unravelling Food Supply Chains in Ethiopia: The Supply Chain of Teff from Major Production Centres to Addis Ababa. Ethiopia Strategy Support Program II'. *Working Paper* 54.

Minten, B., Tamru, S., Engida, E. and Kuma, T. (2013b). 'Ethiopia's Value Chains on the Move: The Case of Teff. Ethiopia Strategy Support Program II'. *Working Paper* 52.

Orr, A., Amede, T., Tsusaka, T., Tiba, Z., Dejen, A., Teklewold Deneke, T. and Phiri, A. (2017) 'Risk Management Scoping Study'. *Working Paper*. 22 February. Smallholder Risk Management Solutions (SRMS) in Malawi and Ethiopia. Oxford: Oxford Policy Management.

OPM (2016) Sustainable Agricultural Intensification Research and Learning in Africa: Smallholder Risk Management Solutions in Ethiopia and Malawi. Project Proposal.

Rosell, S. (2011) 'Regional perspective on rainfall change and variability in the central Highlands of Ethiopia, 1978–2007'. *Applied Geography* 31: 329–338.

Rosell, S. and Holmer, B. (2015) 'Erratic rainfall and its consequences for the cultivation of teff in two adjacent areas in South Wollo, Ethiopia'. *Norsk Geografisk Tidsskrift* 69(1): 38–46.

Weber, J. and Tiba, Z. (2017) 'Value Chain Study and Design of a Replicable Business Model in South Wollo Zone, Amhara Region of Ethiopia'. *Working Paper*. 29 September. Smallholder Risk Management Solutions (SRMS) in Malawi and Ethiopia. Oxford: Oxford Policy Management.